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Deadlift Exercise with Shoes or Barefoot: Effects on Balance and Postural Control in Men and Women

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SUMMARY

Objective. The purpose of this study was to compare the plantar surface area, maximum peak pressure, mean pressure and stabilometry variables between men and women before and after performing the deadlift exercise with shoes *vs* barefoot.

Methods. Thirty healthy participants were selected and separated into two groups: men (n = 15) and women (n = 15). All study participants performed the deadlift exercise with shoes and barefoot at random. Participants performed 3 sets maximal repetitions trials, with intensity of 80% of the body mass and 2-minute rest between the sets. The interval between exercise sessions was separated by 48 hours. Participants underwent evaluations in the baropodometry platform (static conditions) during baseline, immediately post effort, 5-, 10- and 30-minutes post deadlift exercise, with the participant barefoot, to assess of the plantar surface area of both feet (cm^2), maximum peak pressure (kgf/cm^2), mean pressure (kgf/cm^2), anteroposterior (mm/s) and anteroposterior oscillation (mm/s).

Results. Two-way ANOVA showed significant decrease in both anteroposterior ($p < 0.05$) and laterolateral ($p < 0.001$) oscillations at men and women post-barefoot training. Plantar surface area maximal and mean pressure were significantly lower ($p < 0.05$) from 10 min at men and women post-barefoot training. On the other hand, plantar surface area maximal pressure in the right foot of women was significantly lower ($p < 0.001$) from 5 min post-barefoot training.

Conclusions. The results of this investigation confirm that barefoot deadlift exercise contributed to smaller anteroposterior oscillation, laterolateral oscillation and decrease of the plantar surface area pressure in both sexes.

KEY WORDS

Deadlift exercise; stability; baropometry platform; sex difference; postural control.

INTRODUCTION

Free-weights for resistance training utilize isotonic resistance that provides the same amount of resistance throughout the range of motion; thus, free-weights allow for movement in multiple planes requiring balance by the executioner himself (1, 2). Furthermore, free-weights training has been an important tool for joint rehabilitation and neuromuscular conditioning, consequently, provide an important role in the coordination, pattern of neuromuscular recruitment, balance and postural stability, not only when motionless, but also during movement (3, 4). Particularly, the deadlift is a multiple-joint exercise, thus presents a large mechanical stimulus to legs, hip, back, and torso muscles that lead to adaptations for the development of strength, power and balance (5, 6). But, interestingly, regarding balance and postural stability, there are a limited number of studies that comparing deadlift exercise with shoes *versus* barefoot between men and women.

The balance is defined as the condition in which all the forces acting on the body are balanced in the center of the mass and controlled by the support base, in a static or dynamic condition (7-9). These balance conditions are characterized, respectively, by the absence or presence of speed. However, the ability to maintain balance during voluntary activities and to react to external perturbations becomes considerably more complex due to different changes, such as the decrease in the size of the support base, changes in the center of pressure, and postural changes (7-9). Hence, a body presents its state of normal balance when the sum of all external forces and all external torques is equal to zero (8-10). It is noteworthy that the foot helps support, move the body and to absorb ground reaction forces during locomotion, which are the foundations of the human balance and posture, *i.e.*, these functions depend largely on the plantar vault, formed by the longitudinal medial and transverse arches (7, 9, 10).

Anatomical or biomechanical variations between men and women can directly intervene in balance and plantar pressure. Some studies reported differences in feet and gait-related anatomy and habits between men and women (11, 12). Other studies showed that men had a foot longer, higher plantar fascia and heel fat pad thickness compared with women (13, 14). In general, men and women feet are different to varying degrees with respect to arch lateral side of the foot, the first toe, heel-to-toe length, ball length, ball width, ball circumference, malleoli height, and arch dimensions (11, 13, 14).

These differences anatomical or biomechanical of the feet between sex should be taken into account in relation balance and postural stability during deadlift exercise with shoes *versus* barefoot. The absence of data supports the need for additional studies in this area. Hence, the purpose of this study was to compare the plantar surface area, maximum peak pressure, mean pressure and stabilometry variables between men and women before and after performing the deadlift exercise with shoes *vs* barefoot. We hypothesized that both sexes would show a better of the balance and postural stability training barefoot.

METHODS

Study design

This is an analytic observational study. The sample size was determined by including all participants that complied with the eligibility criteria. All participants (men and women) were regular practitioners of resistance exercise and performed 3 sets of maximum repetitions of the deadlift exercise with shoes and barefoot at random. Participants underwent to two evaluations (when training with shoes and when training barefoot) in the baropodometry platform (static conditions) during baseline, immediately post effort, 5-, 10- and 30-minutes post deadlift exercise. All evaluations were performed in a two-session separated by 48 hours, with the participant barefoot, to assess of the plantar surface area of both feet (cm^2), maximum peak pressure (kgf/cm^2), mean pressure (kgf/cm^2), anteroposterior (mm/s) and anteroposterior oscillation (mm/s). All assessment were taken in a temperature-controlled environment (temperature 21 °C, 65% relative humidity) by a Hygro-Thermometer with Humidity Alert (Extech Instruments, Massachusetts, EUA). All assessments occurred between 2:00 and 4:00 P.M.

Participants

This study included 30 participants healthy and separated into two groups: men (age: 28.6 ± 6.7 years; height: 178.2 ± 6.5 cm; body mass: 82.5 ± 5.5 kg; body fat: 15.1 ± 3.7%; n = 15) and women (age: 27.5 ± 7.1 years; height: 165.2 ± 4.5 cm; body mass: 63.6 ± 6.8 kg; body fat: 19.2 ± 4.2%, n = 15). The participants' training frequency was 5.2 ± 0.6 days/week^{-1} with a mean duration for each session training of 65 min^{-1} using resistance-training programs. Subjects with at least one year of resistance exercise experience were included to participate in the current study. All participants performed a routine of resistance training programs used an intensity between 60% and 80% 1RM and a routine of strength training that engaged the whole body with resistance bands, free-weights, dumbbells and medicine balls. The personal shoes selected were shoes usually worn during daily activities within the last 2 months (15).

The participants were eligible if they weren't smokers for the previous 3 months or more, had no cardiovascular or metabolic diseases, systemic hypertension (140/90 mm Hg or use of antihypertensive medication), recent musculoskeletal injury and surgery (in the last 6 months), or pain in any region of the body, and had not used anabolic steroids, drugs or any medication with the potential to impact physical performance (self-reported). This study was approved by the Ethical Committee for Human Experiments of the Augusto Motta University Center, Rio de Janeiro, Brazil (CAAE: 53875421.0.0000.5235 – Date of approval: October 10, 2021). The present study was conducted at the A&D training center high performance, Rio de Janeiro, Brazil. All participants were informed of the experimental procedures and gave written informed consent prior to participation. No clinical problems occurred during the study.

Anthropometric measurements

Body composition was measured following an 8-h overnight fast by bioelectrical impedance analysis using a device with built-in hand and foot electrodes (BIO 720, Avanutri, Rio de Janeiro, Brasil). The participants wore their normal indoor clothing and were instructed to stand barefoot in an upright position with both feet on separate electrodes on the device's surface and with their arms abducted and both hands gripping two separate electrodes on each handle of the device. All biometric measurements were carried out in an air-conditioned room (21 °C). No clinical problems occurred during the study.

Baropodometry assessment

The baropodometry platform consisted of a support with a 655 mm long and 534 mm wide (BaroScan®, Londrina, Brazil). The board contained 4,096 platinums electronic sensors covered by an alveolar rubber captor that gives pressure information from each foot through a USB cable to the computer for an appropriate software (BaroSys). The sampling rate was set at 100 Hz for static assessment. Before assessments, all individuals remained in a standing, bipedal position with the arms pending along the body over the platform with their eyes open mirrored to a fixed point on the wall of the examination room. All assessments took place with the participant barefoot. During static conditions, the subjects stood on the platform in an orthostatic position for 5 s (**figure 1**). The following parameters were considered in static condition: plantar surface area of both feet (cm^2), maximum peak pressure (kgf/cm^2), mean pressure (kgf/cm^2), anteroposterior (mm/s) and anteroposterior oscillation (mm/s). The forefoot was assumed as the foot part anterior to the gravity center and the hindfoot as the part posterior to the center of gravity registered on the device.

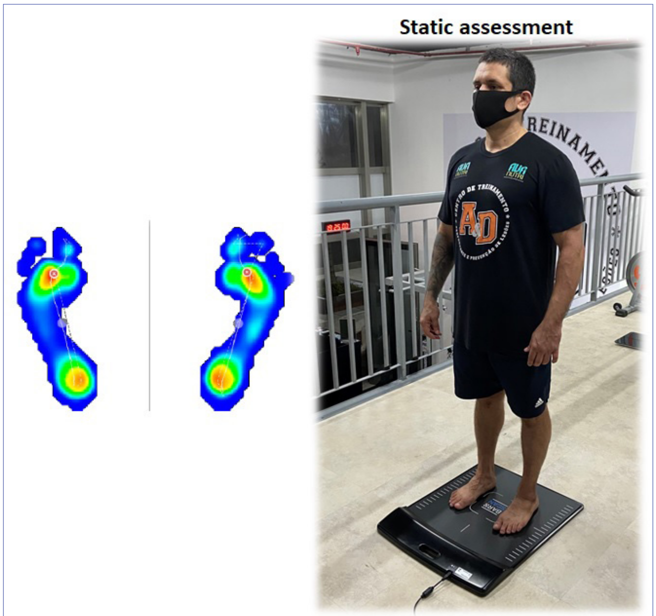

Figure 1. Positioning for performing static assessments on the stability platform.

Exercise protocol

To measure balance and postural stability, the deadlift exercise was selected for promoting greater safety during the execution of the movement (3). All study participants performed the deadlift exercise with shoes and barefoot at random. The interval between exercise sessions (shoes and barefoot) was separated by 48 hours.

Prior to the deadlift exercise protocol, a 10-minute warm-up was performed that included 5 minutes of cycling at 50 W while maintaining a cadence of 60-70 rpm on a cycle ergometer, followed by 10 repetitions in the deadlift exercise at 40% of the athlete's body mass (BM). After the warm-up, the subjects were allowed 4 minutes of passive rest, followed by 3 sets maximal repetitions trials during the deadlift exercise at 80% of the BM, with a 2-minute rest between the sets.

The conventional deadlift was performed with bar was positioned on the floor over the distal end of the metatarsals, the equal load on each side, both hands pronated, and toes should be pointed forward. During concentric phase, the participants kept the head neutral, core muscle activated, and the arms fully extended. When lifting the bar off the floor, all participants should extend their hips and knees. During eccentric phase, the participants kept the head neutral, flat back position and performed a hip and knee flexion returning the bar to the starting position. Training load was calculated by the multiplication of rate of perceived exertion (RPE) by the training session duration *Training load = session RPE × duration (minutes)*. On the other hand, absolute volume load was calculated using the equation: number of sets × number of repetitions × weight lifted (kg) (16).

Statistical analysis

All data are presented as mean ± SD. Statistical analysis was initially performed using the Shapiro-Wilk normality test and the homocedasticity test (Bartlett criterion). To test the reproducibility between the tests, the intraclass correlation coefficient (ICC) was used. For between groups comparisons for change in training session duration, volume load and training load, independent samples t-test was employed. However, to express the differences in RPE values the Chi Squared non-parametric null hypothesis test was also performed. Two-way analysis of variance (ANOVA) was used to test for main and interaction effects of the group (men *vs* women) and timing of measurement for each outcome variable independently (right *vs* left) and the *post hoc* Bonferroni was used to possibility a statistically significant. The significance level was set at 0.05 and the software used for statistics was GraphPad® (Prism 6.0, San Diego, CA, USA).

Table I. Mea n ± SD values of performance variables during deadlift exercise.

		Shoes	Barefoot	95%CI	p
Training session duration (min.)	Men	11.87 ± 2.9	11.40 ± 2.75	0.46 (-1.64 to 2.57)	0.65
	Women	12.67 ± 2.38	12.33 ± 2.29	0.33 (-1.41 to 2.08)	0.69
Volume load (kg)	Men	3673.41 ± 1337.40	4419.79 ± 1807.63	-746.4 (-1935 to 442.7)	0.20
	Women	3104.49 ± 991.42	3430.43 ± 1492.57	-325.9 (-1273 to 621.6)	0.48
Training load (A.U.)	Men	83.33 ± 24.84	81.73 ± 28.40	1.60 (-18.35 to 21.55)	0.87
	Women	89.27 ± 21.85	86.40 ± 19.20	2.86 (-12.51 to 18.25)	0.70
RPE (A.U.)	Men	7 ± 1.07	7.13 ± 1.46	-0.13 (-1.08 to 0.82)	0.77
	Women	7 ± 0.93	7 ± 0.93	-0.00 (-0.69 to 0.69)	1.0

RPE: Rate of Perceived Exertion; A.U.: arbitrary unit.

RESULTS

Table I represents the values of training session duration, volume load, training load and RPE during deadlift exercise. Statistical results no showed a significant difference between men and women with shoes *vs* barefoot.

All analyzed data presented normal distribution. The two-way ANOVA yielded main effects for group at men and women in the anteroposterior oscillation (men: $F_{1,140} = 25.66$, $p < 0.0001$; women: $F_{1,140} = 46.16$, $p < 0.0001$) and laterolateral oscillation (men: $F_{1,140} = 19.61$, $p < 0.0001$; women: $F_{1,140} = 30.87$, $p < 0.0001$) such that Bonferroni *post-hoc* showed significant decrease at men (**figure 2**) and women (**figure 3**) barefoot immediately post-effort in anteroposterior oscillations and laterolateral oscillation from 10 min post effort.

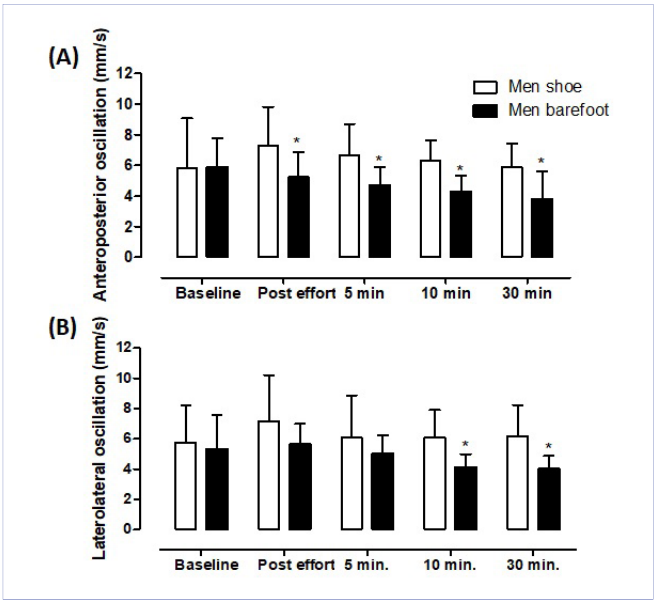

Figure 2. Comparisons of stabilometry variables between shoes and barefoot men.

*p < 0.05 shoes *vs* barefoot.

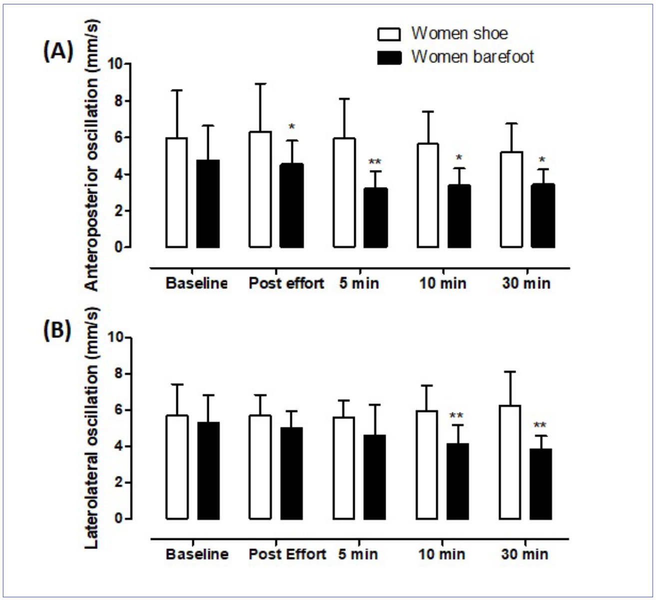

Figure 3. Comparisons of stabilometry variables between shoes and barefoot women.

*p < 0.05 shoes *vs* barefoot; **p < 0.001 shoes *vs* barefoot.

Figure 4 showed that two-way ANOVA yielded main effects for group at men and women in right foot (men: $F_{1,140} = 20.06$, $p < 0.0001$; women: $F_{1,140} = 25.07$, $p < 0.0001$) and left foot (men: $F_{1,140} = 15.63$, $p < 0.0001$; women: $F_{1,140} = 17.99$, $p < 0.0001$) in the plantar surface area maximal pressure (kgf/cm^2), such that Bonferroni *post-hoc* showed significant differences from 10 min post effort between shoes *vs* barefoot at men and women (**figure 4A,B,D**). On the other hand, plantar surface area maximal pressure in the right foot of women was significantly lower ($p < 0.001$) from 5 min post effort to barefoot training (**figure 4C**).

Figure 5 showed that two-way ANOVA yielded main effects for group at men and women in right foot (men: $F_{1,140} =$

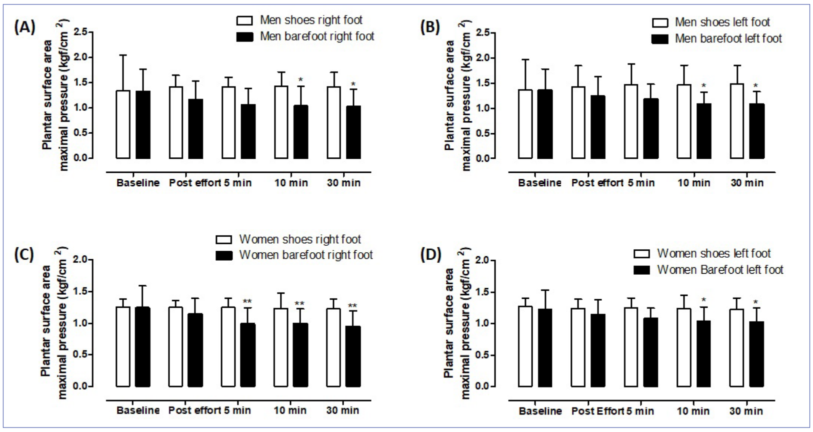

Figure 4. Comparisons of plantar surface area maximal pressure (kgf/cm²) between shoes *vs* barefoot at men and women.

*p < 0.05 shoes *vs* barefoot; **p < 0.001 shoes *vs* barefoot.

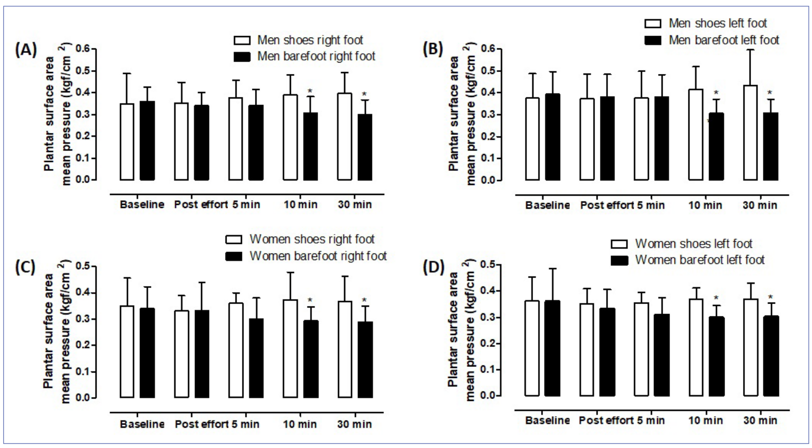

Figure 5. Comparisons of plantar surface area mean pressure (kgf/cm²) between shoes *vs* barefoot at men and women.

*p < 0.05 shoes *vs* barefoot.

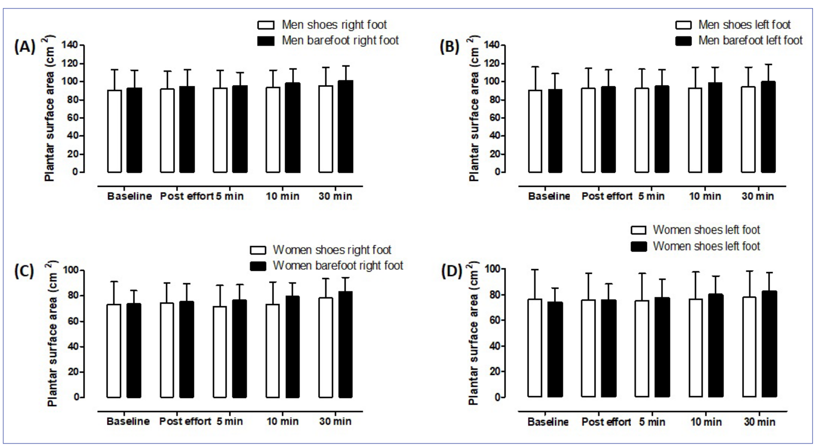

Figure 6. Comparisons of plantar surface area (cm²) between shoes *vs* barefoot at men and women.

9.47, $p < 0.002$; women: $F_{1,140} = 11.54$, $p < 0.000$) and left foot (men: $F_{1,140} = 5.24$, $p < 0.002$; women: $F_{1,140} = 12.56$, $p < 0.000$) in the plantar surface area mean pressure (kgf/cm²), such that Bonferroni *post-hoc* showed significant differences from 10 min post effort between shoes *vs* barefoot at men and women (**figure 5A-D**). On the other hand, no significant difference was observed in plantar surface area (cm²) between men and women with shoes *vs* barefoot (**figure 6**).

DISCUSSION

This study aimed at investigating the effects of deadlift exercise with shoes or barefoot in the balance and postural stability between men and women trained. The main results obtained with this study were that 1) men and women showed significant decrease immediately post-effort in anteroposterior and laterolateral oscillation from 10 min post effort when to train barefoot, 2) plantar surface area maximal and mean pressure showed significant decrease when men and women performed barefoot deadlift exercise. Postural control is defined as the ability to maintain an erect posture of the body. Thus, for the proper functioning of postural control, the integration of sensory motor information into the central nervous system is necessary. Specifically, the control of body position is closely integrated with the somatosensory (sensory receptors located in skin, joints, muscles, and tendons), vestibular (labyrinth, cochlear nerves, nuclei, pathways, and interrelations in the central nervous system) and visual systems (8, 9, 17). When these three systems are is a perfect spatial orientation that triggers ocular (vestibule-ocular, optokinetic, cervical-ocular) and spinal (vestibulospinal, vestibular-colic, cervical-colic, cervical-spinal) reflexes appropriate to the automatic and unconscious maintenance of postural control in the environment (10, 17). Furthermore, the muscular control and the dynamic maintenance of balance, involve the coordinated activity of the muscular kinetic chains organized in directions and planes in which the propulsive forces of the body propagate (3, 18). Specifically, the participation of the feet in postural control depends on the plantar cutaneous stimulations, shape of the arch and the location of the line of gravity at a given moment (19).

Our results showed a worsened postural control by increasing the laterolateral and anteroposterior oscillations after deadlift exercise with shoes in men and women. On the other hand, it becomes evident that smaller the oscillations, the greater the tendency to postural control in the orthostatic position observed in barefoot training. Despite the limitation of studies investigating postural control with shoes *vs* barefoot, one study observed larger displacements in the laterolateral oscillations during performing the deadlift exercise with shoes (3). However, the authors found no significant differences in anteriorposterior oscillations. In contrast, shoes produce instability, decrease rate of force development and indirect ground reaction force (GRF) transmission, thereby compromising lifting performance (3, 15, 20). Contrary, the barefoot lifting could be considered more efficient than shod lifting by integration of the force × velocity curve during the concentric phase and resulting in better motor control that contribute with a steady state sooner which could potentially explain the increased rate of force development while barefoot (3, 21). We hypothesized that the barefoot training contributes with improvement plantar cutaneous sensitivity and somatosensory information from the foot, which help in postural control when exercises were performed barefoot (22). It has also been observed that walk barefoot or minimally-shod showed stronger and larger abductor hallucis and abductor digiti minimi muscles (15, 20). Furthermore, during barefoot training, it seems that the plantar flexors and dorsiflexors muscles are of great importance during postural control in the sagittal plane and the maintenance of frontal plane postural control is modulated by hip flexores and extensores muscles (10, 23, 24). On the other hand, it has been observed that the footwear features affect the cross-sectional areas of foot muscles contributing with weaker intrinsic foot muscles that may predispose individuals to reduced foot stiffness and potentially flat foot (20). In view of these concepts, the shoe may selectively activate specific muscle fiber types, with potential for implications on muscle fatigue, postural control and athletic performance (20, 22).

Despite the anatomical or biomechanical variations between sex can directly intervene in plantar surface area, studies measuring plantar surface area pressure in men and women with shoes *vs* barefoot before and after deadlift exercise are limited. Our results showed decrease of the plantar surface area maximal and mean pressure when men and women performed barefoot deadlift exercise. Despite limited scientific evidence, it has been observed that habitually barefoot training contributes with wider feet, particular in the toe region feature, that enhances three points of contact (heel, first metatarsal, and fifth metatarsal) (25-27). Hence, less center of pressure shift, less energy is wasted on controlling an unstable foot (*i.e.*, increased center of pressure shifts while in shod conditions) and more even distribution of pressure across the foot when habitually barefoot training (25-27). This response possibly promotes reduced muscle tension and may contribute to the increase in plantar surface area due to the impact on motor control, thus it favors the reduction in the plantar surface area maximal and mean pressure by efficiency of the movement with barefoot training in both sexes. In general, shod training can constrict the structure and function of the foot and affects the kinematics and kinetics of movement (11, 14, 20, 27).

The limitations of the study include the absence of measures of muscle thickness and electromyographic evaluation, which would be interesting; however, this yet does not limit the answer to the study question. In addition, longitudinal studies are needed to define a cause-and-effect relationship between sex differences.

CONCLUSIONS

The results of this investigation confirm that barefoot deadlift exercise contributed to smaller anteroposterior oscillation, laterolateral oscillation and decrease of the plantar surface area pressure (maximal and mean) in both sexes. These data contribute to the qualitative and quantitative understanding that barefoot training should be recognized and utilized in both fitness and rehabilitative fields for its potential benefits, especially considering the potential gains in balance and stability. Thus, these results may be a helpful for coaches, physicians and physical therapists regarding neuromuscular performance, injury prevention and recovery strategies.

FUNDINGS

None.

DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

ASM: design, analysis and interpretation of data, writing – original draft, writing – review & editing. LFdS: design, analysis and interpretation of data, writing – review & editing.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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